

EXP-56
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ACCELERATOR EXPERIMENT--Initial Test of the Main Ring
Vertical Beam Damper

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1. The Resistive Wall Instability

Above an intensity of 10^{12} ppp the main ring beam suffers from a vertical coherent instability, the resistive wall effect which causes a sudden loss of more than half the circulating beam. The instability has a growth time of a few milliseconds at injection and sometimes occurs at other points in the acceleration cycle with longer growth time. The instability can be removed by introducing a tune spread with octupoles, but at higher intensities this tune spread becomes comparable with the spacing of the non linear resonances and restricts the transmission of the main ring. At 6×10^{12} the detrimental effect of tune spread is already apparent and above 10^{13} it will be prohibitive.

An alternative cure for the instability, and one which does not have these undesirable side effects, is to damp out the coherent motion with an active feedback system. In this a beam position signal is fed to a parallel plate deflector elsewhere in the ring.

Feedback systems have been used for this purpose on other accelerators and were proposed for the NAL main ring in 1971 by Ruggerio, (1)

2. Observations of the Coherent Instability

We have analysed the coherent motion stimulated by the instability and found it to consist of a superposition of a few standing waves of low mode number. These start with the first of the unstable modes $m = 20$, just above the nominal tune ($\nu_y = 19.2$). The standing wave precesses slowly around the ring in such a manner that the center of charge of any group of protons executes oscillations at the coherent betatron frequency, $\omega_0 - \nu_y$. On the other hand the signal seen by a vertical pickup electrode records the passage of the standing wave modes and contains the frequencies:

$$\omega_0(m - \nu_y) \quad , \quad m = 20, 21 \dots 26$$

a spectrum from 30 kHz to 350 kHz. ($\omega_0 = 47$ kHz).

3. The Beam Damper

The beam damper designed by Q. Kerns consists of a pair of vertical deflecting plates 120 cm long and with 5 cm separation. A power supply applies a voltage of up to ± 2 kV which follows the amplified signal from a vertical pick up station. The bandwidth, 10 kHz to 1 MHz, is more than adequate to embrace the mode frequencies observed.

The position detector at A2I (made by E. Higgins) has the property that it reports the beam position independent of intensity except for a small range where its sensitivity becomes zero for a weak beam. This signal is fed around the circumference in the opposite sense to the protons to meet them as they reach the damper at F11 when they have completed three

quarters of a turn and have executed 15.27 betatron oscillations (Figure 1). The betatron phase advance from deflector to damper is therefore close to an odd multiple of 90° . A mile of coaxial cable is used to adjust the delay of the signal to be in coincidence with the protons at the damper plates.

Figure 1 shows the potential difference appearing between the deflecting plates due to the passage of one Booster batch ($1.6 \mu s$) 4mm off center at A21. From this we deduce the gain to be 8×10^{-4} milliradian deflection per millimeter displacement at A21.

W. Lee has calculated the damping of a 1cm amplitude coherent oscillation under these conditions (Figure 3). The damping time is of the order of 0.5 msec.

4. Damping Coherent Motion Due to Pinger

In order to test the beam damper we induced a coherent betatron oscillation in one booster bunch by pinging the beam 14mm with an air cored device. Without the damper the oscillations, monitored on a vertical pick up, persisted for more than 250 turns without any sign of decay (Figure 4). When the beam damper was switched on the oscillations diminished into the noise with a decay time of about 0.5 msec. Figure 5 shows their decay agreeing very well with W. Lee's computed prediction.

5. Damping of Resistive Wall Effect

The beam damper was also tested at high intensity under conditions where, without strong octupole damping, the resistive wall effect caused the loss of almost 50% of the beam (Figure 6a). It proved completely effective in preventing the instability

when the octupoles were switched off (Figure 6b). Reversing the polarity of the signal on the other hand caused immediate coherent blow up and loss of the beam.

With the octupoles switched off the transmission of the main ring showed a significant improvement and we recommend the damper be used rather than the octupoles in future routine machine operation.

One interesting benefit is that the damper eliminates the coherent oscillations due to injection mis-steering within a few milloseconds of injection. This too seems to improve transmission.

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¹Reference: A.G. Ruggerio - Magnetic System and Electronic Feedback System to Damp Transverse Coherent Beam Oscillations in the NAL Main Ring - NAL - FN-266/0402.

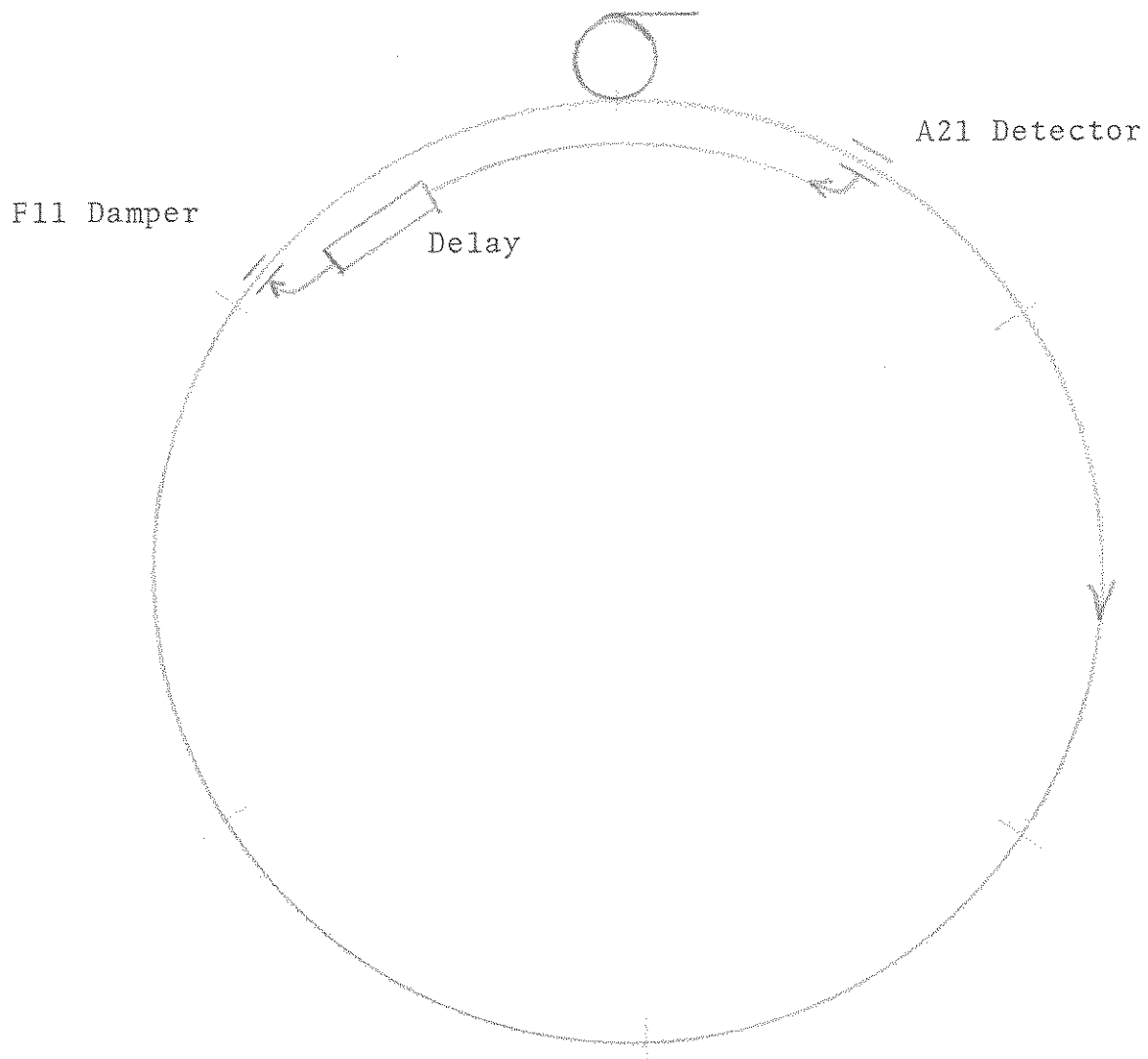
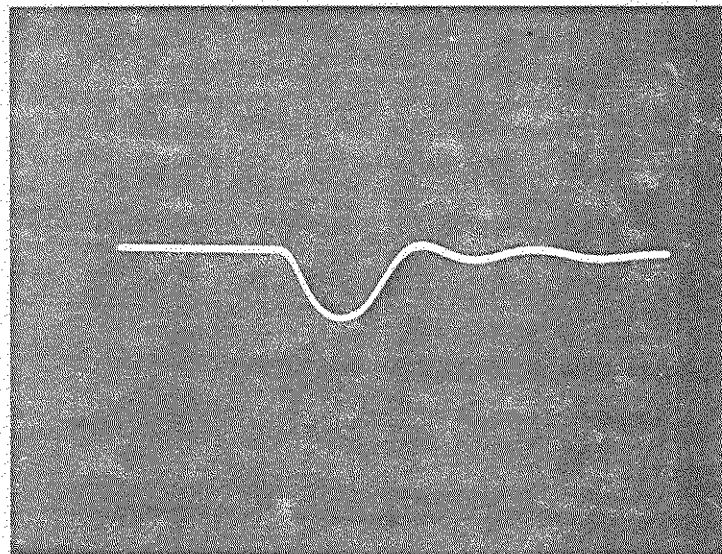


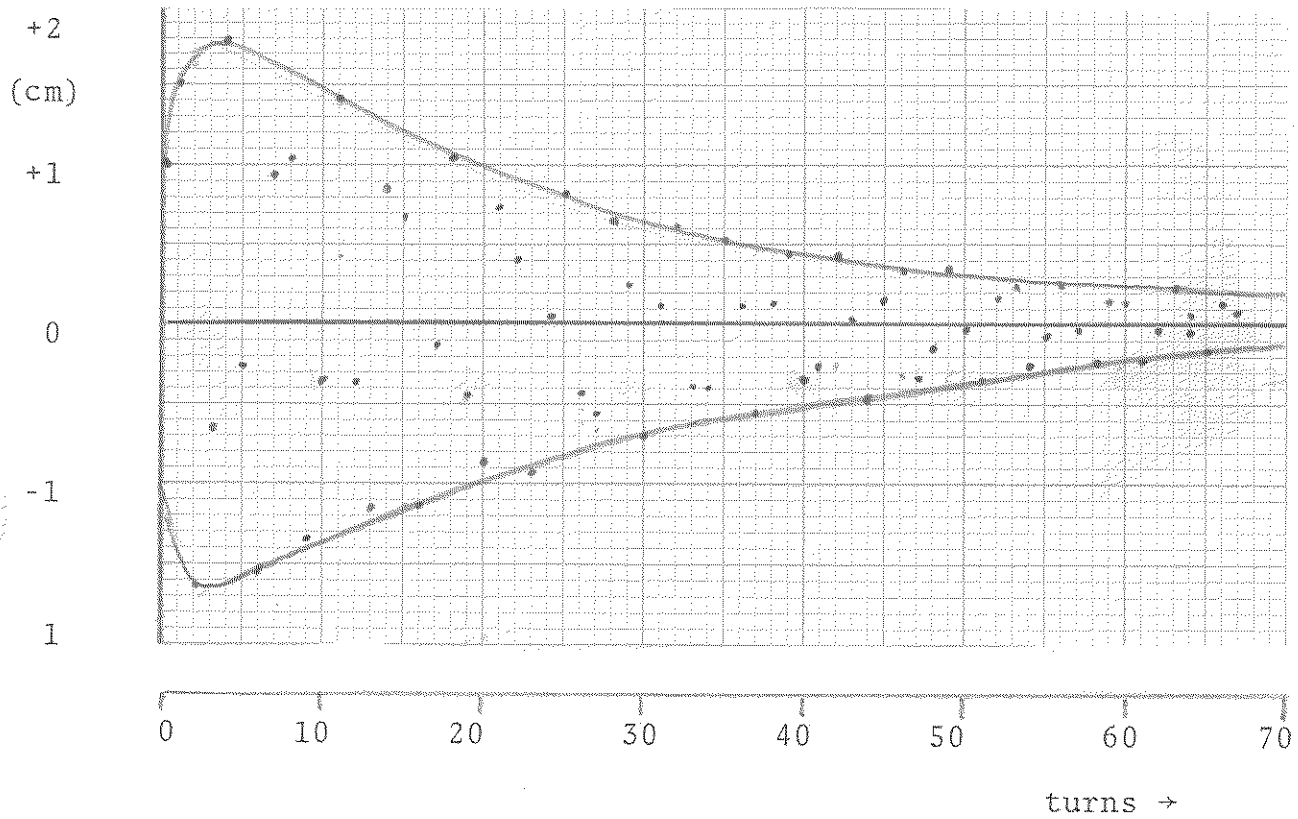
Diagram of Vertical Feedback System

Figure 1



Damper plate voltage waveform for
one booster batch (1.6 μ sec)
(1 μ sec/horizontal division
1kV /vertical division)

Figure 2



Computer simulation of damping coherent
vertical betatron oscillation of initial
amplitude 1cm at $\beta = 95\text{m}$

Figure 3

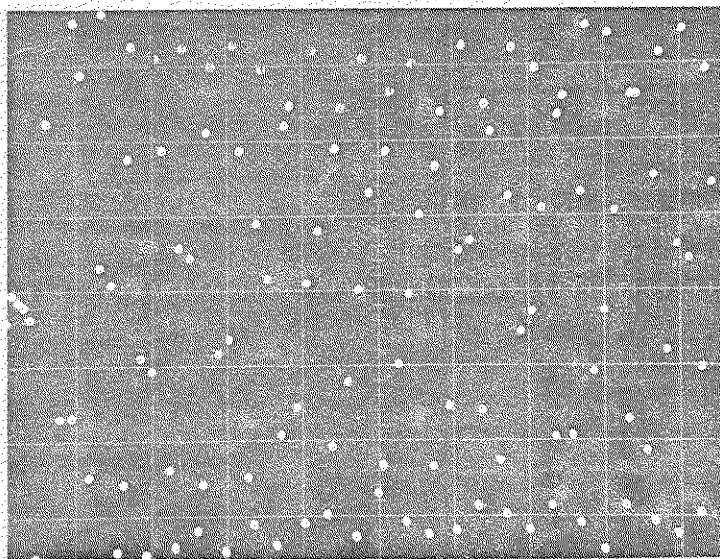


Figure 4
Damper off

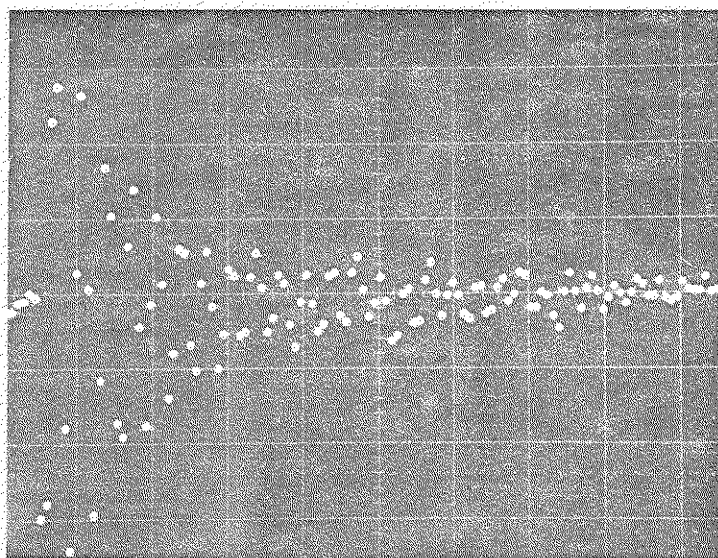
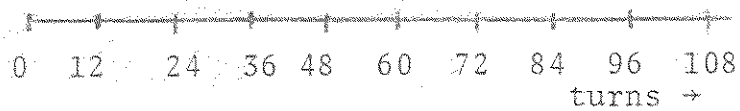


Figure 5
Damper on

Damping a coherent betatron oscillation
of 1.4 cm amplitude at $\beta = 95$